# Power

*Power* is the work done per unit time, or the rate of doing work on an object. As a formula,

$$\mathbf{P = \frac{W}{t} = \frac{\Delta E}{t}}$$

where units are **J/s**, or **watts** (**W**)

If work can be done against the forces of gravity, or inertia, or friction, then power is required to do the work. For example:

- power developed when doing work against gravity is given by:

$$\mathbf{P = \frac{W}{t} = \frac{\Delta E_p}{t} = \frac{mg\Delta h}{t}}$$

- power developed when doing work against inertia (i.e. accelerating) is given by:

$$\mathbf{P = \frac{W}{t} = \frac{\Delta E_k}{t} = \frac{\frac{1}{2}m(v_f^2 - v_i^2)}{t}}$$

- power developed from work done against friction is given by:

$$\mathbf{P = \frac{W}{t} = \frac{F_f d}{t} = \frac{\mu F_N d}{t}}$$

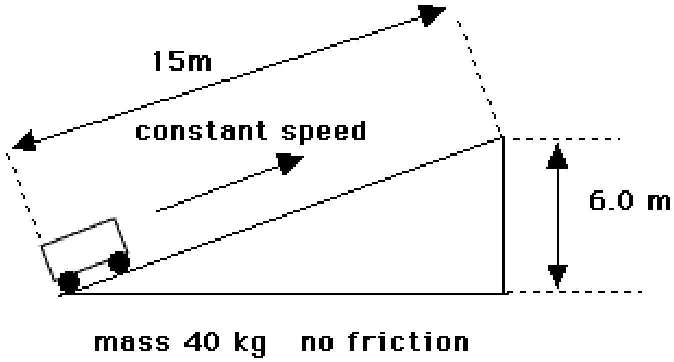
- if work is done on all of these forces at the same time, then the total work is added together and divided by time:

$$\mathbf{P = \frac{mg\Delta h + \frac{1}{2}m(v_f^2 - v_i^2) + \mu F_N d}{t}}$$

**Example #6: A cart accelerates from 0 to 15 m/s in 60 sec. What power is developed if the mass of the car is 20. kg?**

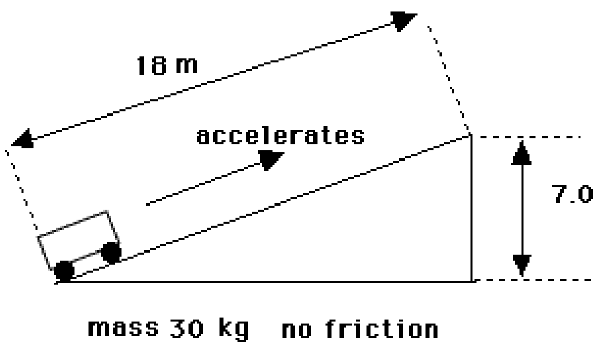
**(see Work-Energy Ex 6 for answer)**

**Example #7: For the diagram below, if the cart goes from the bottom to the top in 16 seconds, how much power was developed?**



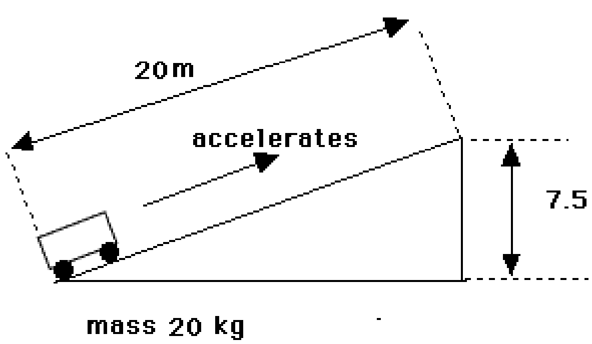

**(see Work-Energy Ex 7 for answer)**

**Example #8: The cart below has an initial speed of 2.0 m/s and accelerates to 5.0 m/s by the time it is at the top of the ramp. How much power is developed? Hint: to find time, use kinematics.**




**(see Work-Energy Ex 8 for answer)**

**Example #9: Here there is a 22° slope. The cart starts from rest at the bottom of the ramp and accelerates to 4.0 m/s by the time it reaches the top of the ramp. With a coefficient of friction $\mu = 0.21$, how much power was developed?**




**(see Work-Energy Ex 9 for answer)**

One last point: a shortcut can be utilized to find average power developed by a moving vehicle of known velocity. To do so, examine the power equation carefully and perform these steps:

$$\mathbf{P} = \frac{W}{t} \quad \rightarrow \text{where} \quad \mathbf{W = Fd} \quad \rightarrow \quad \mathbf{P} = \frac{\mathbf{Fd}}{\mathbf{t}}$$

But recall from kinematics: $\mathbf{d = v_{av}t}$ → $\mathbf{v_{av}} == \frac{d}{t}$

By substitution, a new equation is produced: $\mathbf{P = Fv_{av}}$

This equation shows that the power developed in any moving object is directly proportional to the applied force that created it, as well as the average speed of the object.

**Example #10: A motor driven sled of mass 10.0 kg <u>moves at a constant speed</u> of 15 m/s over a horizontal surface of coefficient of friction $\mu = 0.12$. What power would the motor have to develop to cause this to happen?**

**(see Work-Energy Ex 10 for answer)**